Collaboration with other national and international research groups, both inside and outside of NOAA including Cooperative Institutes and universities, as well as reimbursable support from NOAA and non-NOAA sponsors (1h)

Collaboration at its essence is individuals choosing to work together to achieve more collectively than they could individually – the whole is greater than the sum of the parts. In some instances GFDL staff seeks to work with others and, similarly, in other instances GFDL researchers are sought as a research partner. It is all about seeking to leverage research capabilities and strengths through appropriate partnering. This section is divided into three logical segments. The first lists GFDL's national and international collaboration partners, the second briefly describe GFDL's Cooperative Institute and Cooperative Agreement research partners, and the third lists as a table and then provides abstract level information about outside funded research underway at GFDL.

National and International Collaborations

GFDL scientists collaborate with other scientists around the country and the world. Between 2009 and 2010, GFDL scientists have co-authored over 140 peer-reviewed publications with external collaborators (excluding CICS co-authors) from the following institutions:

U.S. Federal and Federal-Sponsored

1. NOAA Air Resources Laboratory, Silver Spring, Maryland
2. NOAA/NWS/National Hurricane Center, Miami, Florida
3. Lawrence Berkeley National Laboratory, Berkeley, CA
4. Jet Propulsion Laboratory, Pasadena, CA
5. NASA Goddard Institute for Space Studies, New York, NY
6. NASA Goddard Space Flight Center, Greenbelt, MD
7. NCAR, Boulder, CO
8. NOAA/PMEL, Seattle, WA
9. Department of Meteorology, Naval Postgraduate School, Monterey, CA

U.S. Non-Federal

1. Johns Hopkins University, Earth & Planetary Sciences Dept., Baltimore, Maryland
2. Air Resources Board, California Environmental Protection Agency, Sacramento, CA
3. Earth and Space Research, Seattle, WA
4. Center for Atmosphere-Ocean Science, Courant Institute of Mathematical Sciences, NYU, NY
5. Center for Ocean-Atmosphere Prediction Studies, Florida State University, FL

6. Center for Sustainability & the Global Environment (SAGE), Nelson Institute for Environmental Studies, University of Wisconsin, Madison, WI
7. Columbia University, NY
8. Cooperative Institute for Marine & Atmospheric Studies, University of Miami, Miami, FL
9. Department of Atmospheric Sciences, University of Washington, Bothell, WA
10. Department of Civil & Environmental Engineering, Princeton University, Princeton, NJ
11. Department of Civil and Environmental Engineering, University of Washington, Seattle, WA
12. Department of Earth and Space Sciences, Atmospheric & Oceanic Sciences, University of California, Los Angeles, CA
13. Department of Earth Science & Climate Change Institute, University of Maine, Orono, ME
14. Department of Geological Sciences, University of Oregon, Eugene, OR
15. Department of Geology & Geophysics, University of Minnesota, Minneapolis, MN
16. Department of Meteorology, University of Hawaii at Manoa, Honolulu, HI
17. Department of Oceanography, Texas A & M, TX
18. Department of Physics, Texas A & M University, TX
19. Earth & Planetary Sciences Department, Johns Hopkins University, Baltimore, MD
20. Graduate School of Oceanography, University of Rhode Island, Narragansett, RI
21. Institute for Advanced Study, Princeton, NJ
22. Joint Global Change Research Institute, University of Maryland, College Park, MD
23. Massachusetts Institute of Technology, Cambridge, MA
24. Program in Atmospheric & Oceanic Sciences, Princeton University, Princeton, NJ
25. Rosenstiel School of Marine and Atmospheric Science, University of Miami, FL
26. School of Engineering & Applied Sciences & Department of Earth & Planetary Sciences, Harvard University, Cambridge, MA
27. University of North Carolina, Chapel Hill, NC
28. Virginia Institute of Marine Sciences, College of William & Mary, VA
29. Woods Hole Oceanographic Institution, Woods Hole, MA

International – Government, National, and International

1. National Institute of Water and Atmospheric Research, Lauder, New Zealand
2. Norwegian Meteorological Institute, Oslo, Norway
3. Korea Ocean Research & Development Institute, Ansan, South Korea
4. Met Office, Hadley Centre, Exeter, UK

International - Non-Government

1. National Institute of Water and Atmospheric Research, Lauder, New Zealand
2. Laboratoire de Météorologie Dynamique/CNRS/IPSI/Ecole Polytechnique, France
3. L'Ocean/IPSL (CNRS/UPMC/IRD), Paris, France
4. Walker Institute, University of Reading, UK
5. The Abdus Salem International Centre for Theoretical Physics, Trieste, Italy

6. King Abdullah University of Science and Technology, Divisions of Math & Computer Sciences and Engineering/Chemical and Life Sciences and Engineering, Thuwal, Saudi Arabia
7. Optical Remote Sensing, Radio and Space Science, Chalmers University of Technology, Sweden
8. LASG Institute of Atmosphere, Physics, Chinese Academy of Beijing, China
9. University of Bergen, Dept. of Mathematics, Bergen, Norway
10. University of East Anglia, Norwich, United Kingdom; *(Partial funding: Princeton Cooperative Institute for Climate Science//NERC Quatinary Quest Science Fellowship)
11. University of Exeter, College of Engineering, Mathematics & Physical Sciences, Exeter, United Kingdom
12. ICTP, Earth Systems Physics Section, Trieste, Italy
13. University of Victoria, School of Earth & Ocean Sciences, Dept. of Physics, Victoria, BC, Canada; *(SL supported by NA08OAR 4320752 (NOAA/USDC)
14. Norwegian Meteorological Institute, Oslo, Norway
15. Institut de Reserche pour le Developpement/Laboratoire d'Oceanographie et de Climatologie, Experimentations et Approches Numériques, Paris, Cedex 05, France
16. Korea Ocean Research & Development Institute, Ansan, South Korea
17. Liebniz Institute of Atmospheric, Physics @ Rostock University, Kühlungsborn, Germany
18. National Institute of Water & Atmospheric Research, Lauder, New Zealand
19. McGill University, Dept. of Atmospheric & Oceanic Sciences, Montreal, Quebec, Canada
20. Centro de Investigaciones del Mar y la Atmosfera, CONICET-UBA, Buenos Aires, Argentina; *Author Isidoro Orlanski: Supported by Grants NA17RJ2612 and NA-08OAR4320752 – from NOAA/USDC
21. Ocean University of China, College of Environmental Science & Engineering, Qingdao 266100, People's Republic of China
22. Universidad Complutense and Instituto de Geociencia, Madrid, Spain

NOAA Cooperative Institutes and Cooperative Agreement

The following is a brief description of the NOAA Cooperative Institutes with Princeton University and Columbia University for which GFDL is the host, as well as of the NOAA Cooperative Agreement with the University Corporation for Atmospheric Research through which GFDL is able to bring on-board post-doctoral scientists, visiting scientists, and scientific support.

Princeton University's Cooperative Institute for Climate Science and Atmospheric and Oceanic Sciences Program – The relationship between GFDL and Princeton University dates back to before the founding of the Laboratory in 1955. The Laboratory's founding director, Joseph Smagorinsky, began his research career at Princeton University's Institute for Advanced Study. In 1955, the Laboratory was formally established in Washington, DC, but then later returned to Princeton University in 1968 following a competitive process and the construction of a suitable facility. GFDL has been in its current facility ever since.

Current activities sponsored at Cooperative Institute for Climate Science (CICS) fall into one of three tasks, and also within one of three themes. Task 1 is “Administrative Support” and is funded on the order of $100K annually. Task 2 supports post-doctoral scientists and graduate students that work at GFDL with GFDL host scientists and has grown to be funded at more than $2.5M annually. Task 3 is independently funded research and is funded on the order of $0.5M annually. Most of the research under Task 3 is performed by scientists at Princeton University's Main Campus, but some is performed by scientists at other institutions, such as Johns Hopkins University, Rutgers University, the University of Maryland, and the University of New Hampshire.

The three themes are as follows:

1. Earth system modeling and analysis. The development and improvement of Earth system models, that is, models that simulate and aid the understanding of the present climate and Earth system, and that can be used to predict changes in the state of the climate and Earth system. An Earth system model includes components representing the dynamics of the atmosphere, the oceans, the cryosphere, the land its hydrology, and the physical, chemical and biological systems within and affecting these components.

2. Data assimilation. The development of capabilities to assimilate both physical and biogeochemical observations to produce an estimate of the current environmental state for use in Earth system modeling and the prediction of the future state of the climate.

3. Earth system model applications. The use of Earth system models to study the processes associated with long term climate change and variability, and to make predictions of the future state of the Earth system.

Columbia University's Cooperative Institute for Climate Applications and Research (CICAR) – In 2003, NOAA competitively selected Columbia University to host the Cooperative Institute for Climate Applications and Research and named GFDL as the NOAA host Laboratory. GFDL has funded its administrative expenses each year, on the order of slightly more than $100K, and has funded one significant two-year research project and one other small research project. Most of the research undertaken by CICAR for NOAA is supported by the NOAA Climate Program Office.

University Corporation for Atmospheric Research (UCAR) – GFDL has been hosting UCAR scientists for more than a decade through this Climate Program Office-hosted Cooperative Agreement. Scientists and scientific support are brought on through the Visiting Scientist Program and the Joint Office of Scientific Support.

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Reimbursable Research Projects at GFDL

The following is a listing of various research projects currently underway that are being supported by other NOAA and Non-NOAA partners. It identifies the project title, GFDL scientist, other scientist, funding amount, and where appropriate, funding entity. Details on any project are available upon request.

Funding Source	Proposal Title	GFDL Principal Investigator(s)	Co-Investigators	Fiscal Year 2009 Funding	Fiscal Year 2010 Funding
NOAA Climate Program Office	Decadal Climate Predictability and Predictions: Focus on the Atlantic	Thomas Delworth and Anthony Rosati		$118,454	$0
NOAA Climate Program Office	A Collaborative Investigation of the Mechanisms, Predictability and Climate Impacts of Decadal-Scale AMOC Variability Simulated in a Hierarchy of Models	Thomas Delworth and Anthony Rosati	Gokhan Danabasoglu/ NCAR, John Marshall/ MIT, Joseph J. Tribbia/ NCAR	$565,000	$0
NOAA Climate Program Office	A Climate Process Team in Southern Ocean Water Mass Transformation and the Carbon Cycle	John Dunne, Anand Gnanadesikan, and J. Robert Toggweiler	Jorge Sarmiento & Robert Key/CICS, Richard Feely and Chris Sabine/PMEL, Rik Wanninkhof/AOML, Scott Doney/WHOI, Joellen Russel/Univ. of Arizona, Mick Follows/ MIT	$15,000	$12,000
NOAA Climate Program Office	Understanding Discrepancies Between Satellite Observed and GCM-Simulated Precipitation in Response to Surface Warming	Gabriel Vecchi	Brian Soden and Otis Brown/Univ. of Miami	$6,000	$6,000
NOAA Climate Program Office	Using VOCALS to Develop and Evaluate Stratiform Cloud Parameterizations Incorporating Sub-grid Vertical Velocity Variability	Leo J. Donner and Chris Golaz		$112,461	$116,000

Funding Source	Proposal Title	GFDL Principal Investigator(s)	Co-Investigators	Fiscal Year 2009 Funding	Fiscal Year 2010 Funding
NOAA Climate Program Office	CORE - Global Climate Modeling Including Non-CO_2 Greenhouse Gases	V. Ramaswamy		$96,156	$96,156
NOAA Climate Program Office	CORE - Simulate Influence of Greenhouse Gases on Stratospheric Temperatures and Stratospheric Processes	V. Ramaswamy		$140,000	$140,000
NOAA Climate Program Office	CORE - Continue Incorporation of Aerosol-Cloud Microphysics in Global Models to Elucidate Aerosol-Cloud Interaction Effects	V. Ramaswamy		$130,000	$130,000
NOAA Climate Program Office	CORE - Modeling Various Field Data, Including GoMACCS, Using Chemical Transport Models and Calculation of Radiative Forcing of Aerosols for the GPRA Measure	Larry Horowitz and Hiram Levy		$130,000	$130,000
NOAA Climate Program Office	CORE - Model-Observation Comparisons to Link Emissions with Aerosol Properties	V. Ramaswamy		$140,000	$140,000
NOAA Climate Program Office	Improving Climate Predictions by Reducing Uncertainties About CO_2 Fertilization of the Terrestrial Biosphere	John Dunne and Ronald Stouffer	Lars O. Hedin, Stephen Pacala, Elena Schevliakova, Steven Gerber/CICS, Joseph Wright/ Smithsonian Tropical Research Institute	$8,000	$8,000

Funding Source	Proposal Title	GFDL Principal Investigator(s)	Co-Investigators	Fiscal Year 2009 Funding	Fiscal Year 2010 Funding
NOAA OAR/NWS	High-resolution hurricane modeling, adaptive mesh refinement, improved physical parameterizations, wave-ocean coupling, and hurricane-climate-change projections	Morris Bender, S.-J. Lin, and Tim Marchok		$399,600	$461,000
NOAA Climate Program Office	Ocean Data Assimilation	Anthony Rosati		$209,000	$209,000
Office of Naval Research	Improving HWRF and GFDN Coupled Models for Transition to Operations	Morris Bender	Isaac Ginis/URI	$30,000	$33,000
NASA/Goddard Space Flight Center	The Synthesis of Spacecraft Data with a Mars Global Circulation Model	R. John Wilson		$98,959	$102,621
NASA/Goddard Space Flight Center	Development of Standard Implementation Practices and Productivity Software for ESMF-Based MAP Systems	V. Balaji	Max J. Suarez, Arlindo daSilva, Michelle Rienecker, Franco Einaudi/ NASA/GSFC, Chris Hill/ MIT, Paul Schopf/COLA	$110,000	$0
NASA/Goddard Space Flight Center	Development and Testing of a Satellite Simulator Using Climate Model in Support of GLORY Mission	Paul Ginoux and V. Ramaswamy		$35,000	$0
NASA/Goddard Space Flight Center	Detection and Attribution of Spectral TOA forcings and Feedbacks (CLARREO(	V. Ramaswamy		$0	$0

Funding Source	Proposal Title	GFDL Principal Investigator(s)	Co-Investigators	Fiscal Year 2009 Funding	Fiscal Year 2010 Funding
Department of Energy	Using ARM Observations to Evaluate Cloud and Convective Parameterizations and Cloud-Convective-Radiation Interactions in the GFDL Atmospheric General Circulation Model	V. Ramaswamy		$88,461	$92,000
NOAA Climate Program Office	Using Models to Improve Our Ability to Monitor Ocean Uptake of Anthropogenic Carbon	Anand Gnanadesikan	Keith Rodgers/CICS	$60,000	$60,000
NOAA Climate Program Office	Model Development	Brian Gross		$1,097,676	$0
NOAA Climate Program Office	Decadal Climate Predictions and Abrupt Change	Brian Gross		$0	$2,157,808
NOAA Climate Program Office	Global Interoperability (GIP)	V. Balaji		$499,500	$0
NOAA Climate Program Office	Climate Processes Team: Representing Internal-wave Driven Mixing in Global Ocean Models	Robert Hallberg		$0	$349,229
NOAA Climate Program Office	Climate Processes Team: Ocean Mixing Processes Associated with High Spatial Heterogeneity in Sea Ice and the Implication for Climate Process Models	Robert Hallberg		$0	$349,229

Funding Source	Proposal Title	GFDL Principal Investigator(s)	Co-Investigators	Fiscal Year 2009 Funding	Fiscal Year 2010 Funding
NOAA Climate Program Office	Climate Processes Team: Cloud Macrophysical Parameterization and its Application to Aerosol Indirect Effects	Leo J. Donner		$0	$276,494
NOAA Climate Program Office	NSF Travel Funding	Leo J. Donner	Arlene Fiore-Field	$0	$15,000
NOAA National Ocean Service	Modeling the Effects of Climate Change and Acidification on Global Coral Reefs	John Dunne		$0	$130,000
NASA/Goddard Space Flight Center	General Circulation Model Simulations of Martian Dust Storm Activity	R. John Wilson		$0	$91,000
NASA/Ames Research Center	ARC MARS General Circulation Model	R. John Wilson		$0	$90,371
NASA/Goddard Space Flight Center	Toward GEOS-8 – A Non-hydrostatic Modeling Capability	S-J Lin	Max J. Suarez	$0	$188,955
NASA/Goddard Space Flight Center	Effects of Global Change on Asian Pollution Outflow and Long-range Transport	Larry Horowitz		$0	$27,744

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On the pages that follow are abstracts for the current projects, where available. Funding indicated is the amount of funds to be sent by the funding source to GFDL in FY 2009 and future years, and is not a cumulative total of funding to be sent by the funding source to all institutions or for all years:

Decadal Climate Predictability and Predictions Focus on the Atlantic

Thomas L. Delworth and Anthony Rosati/GFDL

FY 2009 Funding: $118,454

Abstract

There is currently limited understanding of the mechanisms of decadal climate variability, and of the potential predictability of the climate system on decadal time scales. Models currently used for decadal and longer climate change projections do not start their projections from the observed state of the ocean. Therefore, a potential source of skill for decadal climate change simulations is neglected. On the decadal scale, the relative roles of forced climate change and internal natural variability may be comparable. Thus, an improved understanding of decadal variability and predictability could lead to significant improvements of decadal scale climate projections. One potentially important region is the Atlantic, where multi-decadal scale warming has apparently led to increased hurricane activity. The relative contributions of anthropogenic forcing and internal variability to that increase of hurricanes is unknown, but it is precisely this question that is crucial for future estimates of hurricane activity.

We describe a systematic program of research activities whose aim is to (i) improve our understanding of the mechanisms of Atlantic decadal variability, (ii) evaluate potential predictability of the climate system, (iii) develop the necessary tools to make decadal climate predictions starting from observed ocean states, and (iv) conduct ensembles of decadal climate predictions starting from estimates of the observed state of the ocean. This research will be primarily conducted using GFDL s CM2.1 global climate model, as well as future climate models currently under development at GFDL. A crucial component of the research will be the further development and use of a novel assimilation technique recently developed at GFDL. The outcome of the research should be (i) an improved understanding of the mechanisms of Atlantic decadal variability, (ii) an evaluation of decadal scale predictability, (iii) a prototype system for making decadal climate predictions, including a newly developed assimilation system that will make state of the art estimates of the ocean from modern observational networks, and (iv) several ensembles of experimental decadal scale forecasts.

A Collaborative Investigation of the Mechanisms, Predictability and Climate Impacts of Decadal-Scale AMOC Variability Simulated in a Hierarchy of Models

Gokhan Danabasoglu/NCAR, Thomas L. Delworth/GFDL, John Marshall/MIT,
Anthony Rosati/GFDL, Joseph J. Tribbia/NCAR

FY 2009 Funding: $565,000

Abstract

The Atlantic Meridional Overturning Circulation (AMOC) of the ocean is a singular feature of the general circulation thought to play a major role in maintaining the climate of the planet. There is an intense interest in developing nowcasting and projection systems for the AMOC because of (i) its association with variations in meridional ocean heat transport, North Atlantic sea surface temperatures and climatic variables such as air temperature, precipitation, drought and severe weather events such as hurricanes, (ii) its potential predictability, (iii) it's possible role in abrupt climate change particularly in response to anthropogenic forcing.

Motivated by this background, here we propose a collaborative study between NCAR, GFDL, and MIT to:

1. Characterize modeled AMOC variability and its climate impacts: past, present, and future,
2. Indentify the mechanism(s) of AMOC variability in the GFDL, MIT, and NCAR coupled models,
3. Explore the extent to which the AMOC is predictable by experimenting with prototype predictability systems initialized by ocean state estimates.

Our study is of particular importance because, as the community embarks on an ambitious program of study of the Atlantic climate variability, a theoretical underpinning analogous to that which motivated modeling and observations of ENSO, is still lacking. It is hoped that by capitalizing on the very significant efforts in coupled global climate modeling and state estimation methodologies at NCAR, GFDL, and MIT and drawing together their complementary strengths, we will make significant progress in each of the above foci areas.

A Climate Process Team in Southern Ocean Water Mass Transformation and the Carbon Cycle

Robert Key/Princeton University, Anand Gnanadesikan, John Dunne, and
Robbie Toggweiler/GFDL, Richard Feely and Chris Sabine/PMEL, Rik Wanninkhof/AOML,
Scott Doney/WHOI/NCAR, Joellen Russel/University of Arizona, Mick Follow/MIT

FY 2009 Funding: $15,000 / FY 2010 Funding: $12,000

Abstract

Climate models are not systematically evaluated against the circulation of the Southern Ocean. This has resulted in IPCC models exhibiting huge ranges in quantities such as the transport of the Antarctic Circumpolar Current (ACC ~00 to 350 Sv; 1 Sverdrup = 10^6 m^3 s^{-1}) and the rate at which dense waters are transformed to light waters within the Southern Ocean (0 to 16 Sv). Unfortunately, published observations of such quantities differ widely as well, making it difficult for modeling groups to know what to aim for in terms of reasonable circulation. This is worrisome because the Southern Ocean is the primary sink for anthropogenic carbon dioxide and plays a central role in the long-term control of the “natural” carbon dioxide content of the atmosphere, with Southern Ocean water mass transformation, which brings old deep water into the upper ocean, playing a disproportionate role in both of these as well as on the magnitude of global biological production. The goal of this Climate Process Team is to evaluate the impact of biases of Southern Ocean circulation on the carbon cycle and to understand the causes for the biases. This will involve: 1. developing and analyzing a wide suite of diagnostics of Southern Ocean circulation to come up with the best possible climatology for the circulation; and 2. evaluating the relative impacts of wind, buoyancy forcing, mixing, and physical and biogeochemical model formulation on those aspects of Southern Ocean ventilation and biogeochemistry most important for the carbon cycle. This will require a combination of theoretical studies and model sensitivity studies.

Understanding Discrepancies between Satellite-Observed and GCM-Simulated Precipitation Change in Response to Surface Warming

Brian J. Soden/RSMAS University of Miami, Gabriel A. Vecchi/GFDL,
Otis Brown/RSMAS University of Miami

FY 2009 Funding: $6,000 / FY 2010 Funding: $6,000

Abstract

All climate models predict that global precipitation will increase in response to surface warming. The rate at which global precipitation increases varies substantially among models,

but all models predict that it will increase more slowly (~1-3%/K) than the rate at which atmospheric water vapor increases (~7%/K). This disparity between the rate of moistening and rate of precipitation increase drives a weakening of the atmospheric circulation (Vecchi and Soden, 2007). The inter-model differences in the response of global precipitation to anthropogenic forcing are directly tied to differences in radiative cooling. However, the cause of inter-model differences in the response of radiative cooling to a warming climate are not understood.

Moreover, several recent observational studies (Allan and Soden 2007, Wentz et al. 2007, Zhang et al. 2007) suggest that precipitation may be increasing at a much faster rate than currently predicted by GCMs. These discrepancies appear at time-scales ranging from interannual, to decadal, to centennial and have important implications for future predictions of climate change, the reliability of the observing system and the monitoring of the global water cycle. If true, such a bias in model projections would have substantial repercussions - not only for the modeling of the atmospheric energy and water budgets, but also for the model projections of the response of the atmospheric and oceanic circulation to increased CO2. However, the veracity of the satellite-observed changes in precipitation remains in question due, in large part, to uncertainties in the retrieval of precipitation from passive microwave sensors.

We propose to better understand the cause of these discrepancies by performing a detailed comparison of SSMI observations and GFDL GCM simulations using a “model-to-satellite” approach in which model output is used to directly simulate the radiances which would be observed by the satellite under those conditions. The advantages of this strategy are that it avoids many of the assumptions that are required when performing retrievals and it provides a model-simulated quantity that is directly comparable to what is actually observed by the satellite. Any assumptions involved in the performing forward radiance simulation are made explicit and can be varied in a controlled framework to examine their sensitivity.

We propose to apply this strategy for comparing model-simulated microwave radiances from the GFDL GCM to the satellite-observed radiances from SSMI. The latest version of the GFDL GCM is well suited for this approach because it explicitly predicts many aspects of the hydrometeor profiles required for simulation of microwave radiances (e.g., the sub-grid distribution of rain rates, rain column heights, ratio of cloud liquid to rain water) and simulations are being performed with resolutions as high as ~30 km which is comparable to nadir footprint of the SSMI pixels. From this comparison we hope to better understand the cause of bias between observed and model-simulated precipitation response to a warming climate.

Using VOCALS to Develop and Evaluate Stratiform Cloud Parameterizations Incorporating Sub-grid Vertical Velocity Variability

Leo J. Donner and Jean-Christopher Golaz/GFDL

FY 2009 Funding: $112,461 / FY 2010 Funding: $116,000

Abstract

We propose to participate in VOCALS Modeling and Regional Experiment (REx) using the GFDL GCM model. The representation of clouds and aerosols in the GCM and the interaction between them will be the focal point of our participation. VOCALS-REx collected data will provide a unique dataset to carefully evaluate GCM prediction of aerosols and clouds in the VOCALS study region. In turn, specific GCM experiments will be conducted to test some of the VOCALS-REx synergy hypotheses. Specifically, we plan to test the effect that anthropogenic aerosols exert on the GCM cloud field. We also intend to investigate whether a poor representation of the marine boundary layer clouds and coastal winds contribute to systematic coupled GCM errors.

Because the GFDL GCM climatology suffers from a negative cloud bias in the VOCALS-REx study region, we also propose to implement and test a new boundary layer cloud parameterization. A key feature of this new parameterization will be the incorporation of sub-grid variability of vertical velocity, temperature and moisture. In particular, the sub-grid vertical velocity information will allow for a more realistic treatment of the activation of clouds condensation nuclei (CCN) in stratiform clouds, and therefore a more realistic representation of the interaction between anthropogenic aerosols and clouds.

CORE - Global Climate Modeling Including Non-CO2 Greenhouse Gases

V. Ramaswamy/GFDL

FY 2009 Funding: $96,156 / FY 2010 Funding: $96,156

Abstract

Quantify the seasonal and spatial characteristics of the global-mean radiative and surface forcing due to the changes in non-CO2 greenhouse gases (methane, nitrous oxide, halocarbons and tropospheric and stratospheric ozone), considering the time periods 1950, 1980 and present. Analyze the influences due to overlap with water vapor, and study the spectral characteristics including the sensitivity to changes in temperature and moisture at different altitudes.

CORE - Simulate Influence of Greenhouse Gases on Stratospheric Temperatures and Stratospheric Processes

V. Ramaswamy/GFDL

FY 2009 Funding: $140,000 / FY 2010 Funding: $140,000

Abstract

Quantify the roles of well-mixed greenhouse gases, ozone and aerosols on the temperature evolution from the upper troposphere to the upper stratosphere (over the period 1979 to 2005) using the NOAA/ GFDL climate model and satellite and radiosonde observations. Examine the Arctic and Antarctic polar seasonal stratospheric changes from the past to the present and into the 21st century. Investigate the ensuing stratospheric effects upon the troposphere. The above issues will be examined using climate model versions with prescribed and prognostic interactive ozone.

CORE - Continue Incorporation of Aerosol-Cloud Microphysics in Global Models to Elucidate Aerosol-Cloud Interaction Effects

V. Ramaswamy/GFDL

FY 2009 Funding: $130,000 / FY 2010 Funding: $130,000

Abstract

Evaluation of the results of the simulations with the new prognostic description of the interactions between aerosols and clouds will continue, with the aim being to determine the robustness of the estimate of the total aerosol forcing (accounting for direct and all indirect effects). In this regard, field observations as well as satellite observations of the relevant aerosol and cloud parameters will be employed. Both mixed-layer ocean and coupled atmosphere-ocean model integrations will be employed to examine the consequences of this forcing and to determine the sensitivity of the climate system due to warm cloud-aerosol interactions.

CORE - Modeling Various Field Data, Including GoMACCS, Using Chemical Transport Models and Calculation of Radiative Forcing of Aerosols for the GPRA Measure

L. Horowitz, H. Levy II/GFDL

FY 2009 Funding: $130,000 / FY 2010 Funding: $130,000

Abstract

Simulations of chemistry-aerosol-cloud-climate interactions will be conducted using the GFDL AM3 atmospheric GCM. Initial development of coupled, interactive stratospheric chemistry, tropospheric chemistry, aerosol, cloud, and radiation modules has been completed. Simulations in AM3 will be used to:

- Reduce uncertainty in the characterization of the optical properties and direct radiative forcing due to greenhouse gases and aerosols.
- Continue evaluation of the simulation of tropospheric and stratospheric species in AM3, and conduct scientific investigations of chemistry-climate couplings.
- Quantifying the space-time distributions of species in the AM3, including differences arising due to the treatment of species as passive/active tracers, and as online/offline characterizations.
- Analyze the sensitivity of the online simulations to the feedbacks involving the model's radiation and thermodynamics. Determining the role of the feedbacks on dust and sea-salt aerosol emissions.
- Investigate aerosol-cloud interactions; estimate magnitude of aerosol indirect radiative forcing.

CORE - Model-Observation Comparisons to Link Emissions with Aerosol Properties

V. Ramaswamy/GFDL

FY 2009 Funding: $140,000 / FY 2010 Funding: $140,000

Abstract

Quantify the roles of the different aerosol species (sea-salt, dust, organic carbon, black carbon, sulfates) in the present-day global radiative forcing using the interactive aerosol module developed as part of the next-generation NOAA/ GFDL Atmospheric Model. Evaluate the reliability by comparing against multiple observations concerning aerosol parameters obtained from ground-based, in situ, field campaigns and satellite observations. Links between emissions from different sources and aerosol physical and optical properties will be evaluated, including influences due to hygroscopicity and internal mixing. The resulting effects on the

radiative and surface forcing will be analyzed. The improvement due to the improved, self-consistent treatment of the interaction between aerosol emissions, meteorology, and radiative heating, in contrast to the usual prescribed aerosol distributions (e.g., AR4 models), will be assessed.

Improving Climate Predictions by Reducing Uncertainties in CO_2 Fertilization of the Terrestrial Biosphere

Lars O. Hedin/Princeton University, Joseph Wright/Smithsonian Tropical Research Institute,
Stephen W. Pacala, Elena Shevliakova and Stefan Gerber/Princeton University,
John P. Dunne and Ronald J. Stouffer/GFDL

FY 2009 Funding: $8,000 / FY 2010 Funding: $8,000

Abstract

This proposal addresses one of the greatest uncertainties in our efforts to model the Earth's coupled carbon climate system: whether nutrient availability will limit the ability of tropical forests to serve as a terrestrial CO_2 sink. Recent evidence from models and field experiments suggest that, while poorly resolved, the terrestrial CO_2 sink might decrease or even become a source of carbon to the atmosphere, and thus further accelerate climate warming. Nutrient limitation of CO_2 fertilization in the tropics represents the single greatest source of uncertainty in the carbon cycle over the next half century. Resolution of this problem would be a major contribution by GFDL to the national debate about carbon mitigation, with substantial implications for policy options.

We propose to bring together a group of experimental, theoretical and modeling scientists to leverage our emerging understanding of plant response to CO_2 under nutrient limitation, with the goal of improving parameterization of the key processes that determine spatial and temporal variability of terrestrial carbon exchange within the GFDL dynamic land model LM3V.

Our goal is to develop a novel intellectual platform that links process-based field studies directly to the LM3V and GFDL Earth system model development. We will take advantage of the considerable observational, intellectual, and experimental infrastructure that exists within the Barro Colorado Island (BCI) research forecasts of the Smithsonian Tropical Research Institute in Panama. These forests represent an ideal model system for lowland tropical forecasts, with high diversity in species and land disturbance conditions, and soils that vary in nitrogen and phosphorus richness. Our proposed work is unique in that land models have not generally been

parameterized directly against observational and experimental data from lowland tropical forests.

To model the nutrient-dependence of CO_2 fertilization in the tropics, our strategy is to first characterize and parameterize the processes that generate and maintain nutrient limitations across tropical ecosystems. Second, we will parameterize the physiological and growth response of plants to variations in nutrient supply rates, using field-based experiments and observations. Third, we will evaluate the emergence of feedbacks between the coupled physical climate and terrestrial nutrient models.

We believe this platform offers a unique opportunity to reduce major scientific uncertainties about the terrestrial carbon sink, its dependence on nutrients, and its feedback onto the larger climate system.

High-Resolution Hurricane Modeling, Adaptive Mesh Refinement, Improved Physical Parameterizations, Wave-Ocean Coupling, and Hurricane-Climate-Change Projections

Morris Bender, S.-J. Lin and Tim Marchok/GFDL

FY 2009 Funding: $399,600 / FY 2010 Funding: $461,000

Abstract- Not Available

Ocean Data Assimilation

Anthony Rosati/GFDL

FY 2009 Funding: $209,000 / FY 2010 Funding: $209,000

Abstract

Estimating the state of the Earth System is critical for monitoring our planet's climate and for predicting changes to it on time scales from months to decades. Toward these ends, the vast number of atmospheric observations and the growing number of ocean observations must be combined with model estimates of the state of the Earth System by means of data assimilation systems. This project explores the development of new data assimilation techniques using state-of-the-art coupled climate models and applies these techniques to detecting climate change, improving forecasts on seasonal to interannual time scales while providing estimates of their uncertainty, and improving our understanding of predictability at decadal time scales in order to provide a foundation for the development of a NOAA capability

for decadal forecasts. This capability will provide the Nation's decision and policy makers with the best possible climate information on critical problems such abrupt climate change, changes in hurricane activity, drought, and sea-level rise.

Improving HWRF and GFDN Coupled Models for Transition to Operations

Isaac Ginis/University of Rhode Island and Morris Bender/GFDL

FY 2009 Funding: $30,000 / FY 2010 Funding: $33,000

Abstract

The forecast operations of both NOAA's Tropical Prediction Center and Navy's Joint Typhoon Warning Center require more accurate HWRF and GFDL/GFDN models as integral parts of the multi-model ensemble forecast efforts. We are requesting support, under the auspices of the Joint Hurricane Testbed (JHT) Program at NOAA, to further improve the performance of the operational HWRF model at the NOAA's National Centers for Environmental Prediction (NCEP) and the operational GFDN model at the Navy's Fleet Numerical Meteorology and Oceanography Center and provide assistance to NCEP and FNMOC in transitioning the model upgrades to operations.

The following are the major tasks to be undertaken:

GFDN model

- Increase spatial resolution from 1/12th to 1/18th degree in the inner mesh
- Couple with the WAVEWATCH III wave model
- Improve physics of the air-sea fluxes, including sea spray effects
- Implement NAVY's NCODA real-time ocean analysis in the Atlantic Basin

HWRF model

- Implement the new URI air-sea interface model (ASIM) coupled with the ESRL sea-spray model
- Assist in testing and evaluation of the improved HWRF-Wave-Ocean coupled system

This work will be conducted in close collaboration with our EMC and FNMOC colleagues, building directly upon our successful previous work on the improvements and operational implementation of the GFDL, HWRF and GFDN model upgrades. We will also collaborate with scientists at ESRL on the implementation of the ESRL sea-spray parameterization scheme.

The Synthesis of Spacecraft Data with a Mars Global Circulation Model

R. John Wilson/GFDL

FY 2009 Funding: $98,959 / FY 2010 Funding: $102,621

Abstract

Mars Global Surveyor (MGS) observations provide the basis for characterizing seasonal and interannual variability in atmospheric thermal structure, dust lifting activity, and cloudiness. The observations include temperatures retrieved from Thermal Emission Spectrometer (TES) spectra and Radio Science occultations, density measurements derived from the Accelerometer experiment, and clouds and dust fronts seen in imagery from the Mars Orbiter Camera (MOC). A significant limitation of the observations is the absence of direct information about the atmospheric circulation. Recently the TES retrievals of temperature and dust column opacity have been used as input to the UK Mars data assimilation system to derive a consistent set of thermal and dynamic fields for the three Mars years observed during the MGS mission. The proposal investigation will use this data set, referred to as the MGS Reanalysis, to document the variability of important components of the atmospheric circulation such as global scale thermal tides, stationary and transient waves. We will also employ the NOAA/GFDL Mars General Circulation Model (MGCM) to explore the relationship between spacecraft observations, the evolving atmospheric circulation and the resulting influence on water ice cloud formations, dust and water vapor transport, and aspects of dust lifting. The MGCM will also be used to identify and correct biases in the assimilation model that result from missing or incomplete physics and errors in the specification of the vertical distribution and radiative properties of aerosols. The characterization of the spatial and seasonal variation of the atmospheric circulation is a fundamental aspect of the description of the Martian atmosphere and climate. A complementary aspect of this research will be the further refinement and validation of the dynamical and physical processes represented in Mars GCMs, which are becoming increasingly powerful tools for describing and predicting the state of the atmosphere and for exploring present and past climate issues.

Development of Standard Implementation Practices and Productivity Software for ESMF-Based MAP Systems

Max J. Suarez, Arlindo daSilva/NASA/GSFC, V. Balaji/GFDL, Michele Rienecker/NASA/GFSC, Chris Hill/MIT, Paul Schopf/COLA, Franco Einaudi/NASA/GSFC

FY 2009 Funding: $110,000

Abstract

Initial experience using the Earth System Modeling Framework (ESMF) has identified the need to standardize the way the framework is implemented in climate models and assimilation systems. Here, we propose to extend the framework by developing usage standards and software tools for building ESMF compliant components. The proposed developments will (1) facilitate the porting of existing codes to ESMF, (2) provide tools and a straightforward recipe for building new ESMF components, and (3) provide much greater interoperability between compliant components than between current ESMF compliant components. We also propose to implement the tools and standards being proposed in the GEOS-5 AGCM, one of the core systems of the MAP program, as well as in several other climate models. We anticipate that their use by other MAP investigators and by the MAP integration group will greatly facilitate the inclusion of diverse applications in MAP systems and enhance the compatibility of these systems and their products with those of other national and international efforts with which we will be collaborating.

Development and Testing of a Satellite Simulator Using Climate Model in Support of the GLORY Mission

V. Ramaswamy and Paul Ginoux/GFDL

FY 2009 Funding: $35,000

Abstract

We propose a 1-year project to develop and test a simulator of the Aerosol Polarimetry Sensor (APS) instrument in support of the GLORY mission to produce, from variables simulated with the GFDL climate model, aerosol properties that are consistent with the retrieved products, and can be compare with other ground-based and satellite products. Our objective is to combine the advantages of the different satellite instruments in the A-train constellation to better evaluate and constrain climate models, and to ultimately improve our understanding of the impacts of aerosol on climate.

Detection and Attribution of Spectral TOA Forcings and Feedbacks (CLARREO)

V. Ramaswamy/GFDL

FY 2009 Funding: $0

Abstract

CLARREO has the potential to provide valuable new measurements that could help detect and estimate radiative forcings and feedbacks under clear sky conditions. The utility of CLARREO for the detection and quantification of cloud feedbacks remains an open issue. The feasibility of separating changes in clouds from changes in the rest of the climate system has not been determined. In solar wavelengths, the feasibility of isolating forcings and feedbacks in the data has yet to be tested. This is a particularly important issue given the large range and uncertainty in low-cloud feedbacks among the models assessed in the IPCC AR4. We propose to conduct a series of Observing System Simulation Experiments (OSSEs) to test the detection and attribution of radiative forcings and feedbacks from the CLARREO data. One of our principal objectives is to quantify the improvement in detection and attribution skill relative to existing instruments.

Climate models treated as surrogates for the real Earth system are ideal tools for these feasibility studies. In climate models, unlike in the real system, it is easy to calculate the forcing terms for each individual radiatively active species, including the long-lived greenhouse gases, ozone, land-use change, and natural, anthropogenic, and volcanic aerosols. It is also possible to calculate the individual feedbacks associated with water vapor, lapse rate, surface albedo, and clouds. Climate models can be used to test whether these forcings and feedbacks can be separated and quantified using the CLARREO data, and if so what are the time scales for unambiguous detection and attribution. The latter question is related to the fidelity of the unforced natural variability in these models. An ensemble of models with a range of interannual variability is essential to avoid any systematic artifacts in the results.

We propose to conduct CLARREO OSSEs with three leading climate models analyzed in the IPCC AR4 that are already instrumented to compute forcings and feedbacks. In order to perform the OSSEs, we will add adding two new components to these models:

- Emulators for the shortwave and infrared CLARREO interferometers; and
- More advanced spectrally resolved treatments of surface spectral albedos.

The results from the instrument emulators will be treated as surrogate CLARREO data and reduced to estimate the forcings and feedbacks calculated directly from the model physics. Many climate models treat the interaction of solar radiation and the surface with relatively

coarse spectral resolution. The improvements in land and ocean surface albedos will enhance the realism of the shortwave calculations for the OSSE.

The results from the OSSE will help answer several critical open questions, including:

1. Can the forcings from aerosols and land-use change and the feedbacks from snow and ice be detected and quantified using CLARREO data?
2. Can the indirect shortwave forcings from aerosol-cloud interactions and the feedbacks from clouds be detected and quantified using CLARREO data?
3. What are the implications of pixel size for the detection and quantification of forcings and feedbacks in clear-sky versus all-sky observations?
4. To what extent is it possible to isolate forcings and feedbacks associated with changes in specific species and processes in the CLARREO measurements?
5. Can the changes in and longwave feedbacks from low, middle, and high clouds be detected and quantified using the CLARREO infrared data?

Using ARM Observations to Evaluate Cloud and Convection Parameterizations and Cloud-Convection-Radiation Interactions in the GFDL Atmospheric General Circulation Model

V. Ramaswamy/GFDL

FY 2009 Funding: $88,461 / FY 2010 Funding: $92,000

Abstract

This proposal summarizes research currently underway at GFDL to develop a new class of cloud and convection parameterizations based on sub-grid probability distribution functions (PDFs) of vertical velocity. These PDFs are subsequently used to generate PDFs of cloud microphysical properties. The approach has been implemented in the GFDL atmospheric model (AM) for deep convection, and a highly simplified implementation for droplet activation has been implemented for stratiform clouds. Together with the GFDL AM radiative transfer parameterization that is calibrated against 'bench-mark' computations, we will set up a platform for the analyses of the resulting cloud-convection-radiation interactions and the associated latent and radiative heating rates and fluxes against available ARM measurements and diagnoses.

The proposal requests an ARM-funded postdoctoral fellow to evaluate the parameterizations, test processes and investigate the interactions using ARM microphysical, radiation, and vertical velocity fields. Direct application of these observations to both general circulation model (GCM) and single-column models (SCMs) is proposed. We also propose use of

large-eddy simulation (LES) and cloud-system-resolving models (CSRMs) as process-level models to understand the interactions among the different processes and to evaluate and develop the GCM parameterizations based on the improved understanding. We propose in particular the use of ARM data to evaluate and develop where necessary these process-level models.

We also propose that the ARM postdoctoral fellow co-ordinate AM tests of these parameterizations in the CCPP-ARM Parameterization Testbed (CAPT) program between GFDL and Program for Climate Model Diagnosis and Intercomparison (PCMDI). Finally, given the availability of radiative heating rates and fluxes from ARM and the importance of accurate representation of them in both process and general circulation models, we propose that the ARM postdoctoral fellow employ ARM-observations to evaluate radiative heating rates in GFDL models, and compare them with the latent heating contribution in the diabatic heating of the atmosphere.

Using Models to Improve our Ability to Monitor Ocean Uptake of Anthropogenic Carbon

Anand Gnanadesikan/GFDL and Keith Rodgers/CICS

FY 2009 Funding: $60,000 / FY 2010 Funding: $60,000

Abstract

There are two main tasks in using measurements to monitor the uptake of carbon dioxide by the ocean. The first task is the identification of the anthropogenic component of ocean carbon measurements along the Repeat Hydrography tracks. The second component is the extrapolation of the anthropogenic carbon inventory to the basin scale. For both cases, monitoring is complicated by variability in ocean circulation, and models provide an important tool in the development of novel methods to reduce uncertainty in estimates of ocean uptake of anthropogenic carbon. A major result thus far involves the role of large-scale planetary waves, which cause a horizontal light water rich in anthropogenic carbon. In a paper in press in J. Geophys. Res., we show that this redistribution can be accounted for using altimetric measurements of sea surface height. Future work involves developing techniques to distinguish between changes in inventory due to adiabatic mechanisms like sea surface height from diabatic changes in ventilation. In the coming year we plan to examine output from the GFDL ESM2.1 in order to evaluate observational strategies for estimating ocean carbon uptake.

Model Development

Brian Gross/GFDL

FY 2009 Funding: $1,097,676

Abstract- Not Available

Decadal Climate Predictions and Abrupt Change

(Model Development in 2009)

Brian Gross/GFDL

FY 2010 Funding: $2,157,808

Abstract

Utilize the new supercomputing resources that will be available as a result of the American Recovery and Reinvestment Act (ARRA) Climate Modeling and Data Records allocation to facilitate development and use of new climate model with high-resolution ocean (ocean grid sizing of 10-20 Km). These new ARRA computing resources will augment the NOAA R&D High Performance Computing System with required processing, data storage and analysis systems. This new hardware will facilitate running ensembles of high resolution model simulations for multiple decades. At this initial stage the ocean will be high resolution (as fine as 10 Km grid), but the atmosphere is medium resolution (100 Km grid).

A new data assimilation system will initialize state of the art climate models using data from the Global Ocean Observing System (GOOS), for routine production of initial conditions for decadal scale predictions. This requires three junior scientists with expertise in observational data and assimilation systems.

Development of coupled climate model with high-resolution ocean. This model will be called CM2.5 and is the target model to run for decadal predictions. It will require two project scientists for rigorous model evaluation and one technical support staff for optimizing code and managing integrations

Post-doctoral support through the Cooperative Institutes will support modeling glaciers, and high resolution climate/carbon/ice/snow models with the intent to transition modeling results to NOAA’s Geophysical Fluid Dynamics Lab (GFDL). This research will support implementation of a forecast capability for sea level rise and a better understanding of Arctic climate impacts.

Global Inoperability (GIP)

V. Balaji/GFDL

FY 2009 Funding: $499,500 / FY 2010 Funding: $0

Abstract- Not Available

Climate Processes Team: Representing Internal-wave Driven Mixing in Global Ocean Models

Robert Hallberg/GFDL

FY 2010 Funding: $349,229

Abstract

The overall goal of this Climate Process Team is to refine, develop and implement dynamically appropriate parameterizations for diapyncal mixing due to internal-wave breaking for use in global climate models. Work will focus on three developments: the maturing of near-field parameterizations accounting for mixing processes at internal wave generation sites, a new parameterization for the mixing resulting from the breakdown of near inertial energy transported in the wave field, and a parameterization for the breakdown of internal wave energy in the ocean interior far away from sources. A combination of data-based relations will be employed for wave physics, radiation balance formulations, and process resolving models of the high-resolution and global-resolution classes.

Dynamical models of the climate represent ocean physics through a vast range of spatial and temporal scales. With the goal of predicting global scale phenomena over decades and centuries, the physical cascade of processes is directly represented only to the mesoscale band. At smaller scales, namely those involved in the dissipation of energy and the diffusion of thermodynamic tracers, the processes must be parameterized. In the case of the ocean interior, only the internal wave field connects the forcing scales of the circulation to the dissipative scale of turbulence. In particular, internal wave driven mixing drives the diabatic evolution of the ocean's deep stratification on the very time scales of central interest to the climate prediction problem. In just over three decades of ocean model development, the parameterization of internal wave driven mixing has evolved from ad hoc schemes involving diffusivity specification, to semi-empirical formulations based on wave energetic and an internal wave source term. While some basic effects of internal wave driven mixing are now present in models, such as the link between rough topography and abyssal circulation, more fundamental relationships between internal waves, mixing, and the overturning circulation remain unresolved. Furthermore, many aspects of the internal wave spectrum remain entirely unrepresented, such

as the near inertial band, and the far-field breakdown of wave energy away from internal wave sources. These involve dynamical balances for wave radiation and its breakdown by wave-wave interactions, which have been formulated in terms of energy relations accessible to process-oriented numerical models. In addition, the radiative physics of internal waves are now directly simulated in the process-resolving global models developed in the last several years (GOLD and HYCOM). These tools have opened the possibility for a new generation of internal wave mixing parameterizations for use in ocean climate models. The development of such parameterizations has been hindered by the lack of direct collaboration across the process observing, theoretical, and ocean modeling working groups; the NOAA/NSF funded ocean Climate Process Team that funds this position is intended to eliminate this obstacle to incorporating physically-based parameterizations of internal wave mining into GFDL's coupled climate models.

Over the course of this multi-year research effort, the research scientist funded by this proposal will engage, both individually and collaboratively, in activities designed to meet the objectives of the team as a whole. These activities may include numerical process studies of internal waves and internal wave-driven mixing, theoretical studies to translate the results of these process studies or sea-going observational studies into appropriate parameterizations for use in coupled climate models, implementation of these new parameterizations in one or more of GFDL's coupled climate models, and the evaluation of the impacts of these processes on climate simulations.

A postdoctoral scientist may be hired by CICS in the coming year to work on this project.

Climate Processes Team: Ocean Mixing Processes Associated with High Spatial Heterogeneity in Sea Ice and the Implications for Climate Process Models

Robert Hallberg/GFDL

FY 2010 Funding: $349,229

Abstract

The objective of this effort is to improve the ocean model representation of processes associated with high spatial heterogeneity in sea ice by implementing multi-column ocean grid (MCOG) ideas in climate models, and by evaluating the sensitivity of the climate system to these parameterizations. The ultimate goal is to reduce uncertainties in both short-term and long-term climate model runs and also to improve the simulations of biogeochemical tracers involving ice-ocean fluxes. This will also set the stage for more realistic ecosystem models in regions affected by sea ice.

In current climate models with coupled multi-category sea ice and ocean models, the heat and tracer flux between the ice and ocean are calculated based on the average of all ice categories and a single ocean column. Use of a single column ice-ocean model showed that resolving the high spatial variability in ice-ocean brine exchange has important implications for ocean mixing and consequent sea ice mass budgets that influence critical climate feedbacks. In particular, multiple ocean columns in each grid with leads that are realistically embedded within the ice cover are needed to improve simulations against Surface Heat Budget for the Arctic Ocean (SHEBA) observations. Currently, this method has not been tested or implemented in any climate models. Since the single column ice-ocean model study was limited to the summer ice melting season and in a 1-D format only, further studies on the multi-column ocean grid (MCOG) and related processes are necessary. Questions to be explored include: How does MCOG work during the ice growth period? How can MCOG be implemented in 3-D climate models? How does MCOG influence physical and biogeochemical tracers that have fluxes between ice and ocean? How much can MCOG reduce uncertainties in climate models? What is the importance of explicitly representing the high ice/ocean flux spatial heterogeneity in climate processes and feedbacks? How will representing this sub-grid-scale variability reduce uncertainties in climate models?

These ideas are still relatively immature, and there is a great need for more systematic study and implementation of MCOG in climate models to reduce uncertainties associated with the high spatial heterogeneity in sea ice. A Climate Process Team has been formed, consisting of ocean-climate model developers, process modelers, theoreticians, and observational scientists, to collaborate and systematically address MCOG related problems and the implementation of these ideas in ocean-climate models.

Over the course of this multi-year research effort, the research scientist funded by this proposal will engage, both individually and collaboratively, in activities designed to meet the objectives of the team as a whole. These activities may include idealized studies of the effects of multi-column ocean grid (MCOG) ideas on the ocean state in ice-covered seas – in particular to identify the key parameters and quantify uncertainties, the implementation of MCOG ideas in GFDL's ocean climate models and coupled climate models (and 3-dimensional ocean models in general), and the physical and biogeochemical impacts of these ideas in coupled climate simulations.

A postdoctoral scientist may be hired by CICS in the coming year to work on this project.

Climate Processes Team: Cloud Macrophysical Parameterization and its Application to Aerosol Indirect Effects

Leo J. Donner/GFDL

FY 2010 Funding: $276,494

Abstract

We will address the problems of subgrid variability and aerosol indirect effects by implementing a novel cloud parameterization, Clouds Unified by Bi-Normals (CLUBB), in the general circulation model (GCM) at GFDL. CLUBB provides a unified, consistent, and general treatment of subgrid variability. CLUBB's methodology is a marked departure from the mass-flux methodology that has existed for decades. CLUBB has two particular advantages for modeling aerosol indirect effects. First, CLUBB can activate aerosol using the full subgrid distribution of updrafts. Second, CLUBB can drive microphysical processes using the joint distribution of moisture, temperature, vertical velocity, and hydrometeors. The chief deliverable of our project is the implementation and testing of CLUBB in GFDL's GCMs. However, our project (through CPT members at University of Washington, NOAA ESRL, and NASA JPL) will include two other deliverables that will have benefits to the field independently of CLUBB. First, we will perform a large-eddy simulation study of the response of clouds to aerosols, which can serve as a benchmark for parameterizations. Second, we will construct several analyses of satellite observations in order to evaluate aerosol indirect effects in GCMs.

NSF Travel Funding

Leo J. Donner and Arlene Fiore-Field/GFDL

FY 2010 Funding: $15,000

Abstract- Not Available

Modeling the Effects of Climate Change and Acidification on Global Coral Reefs

John Dunne/GFDL

FY 2010 Funding: $130,000

Abstract

This collaboration between NOAA's Geophysical Fluid Dynamics Laboratory, the NOAA Coral Reef Watch Program, and the University of British Columbia will project potential effects of climate change and ocean acidification on the frequency of mass coral bleaching events and changes in coral cover. This project will translate coarse predictions from global climate and earth system models into the higher resolution information useable for management and policy decisions and the IPCC Fifth Assessment.

Project description:

A key challenge in managing U.S. coral reefs in an era of climate change and ocean acidification is translating scenarios of future climate projected by coarse resolution earth system models into localized projections for different coral reefs or regions. This project will address this challenge by developing an eco-forecasting model that integrates the data from the global earth system models developed and implemented by GFDL Laboratory and other climate modeling groups, the remotely-sensed oceanographic data products from NOAA Coral Reef Watch, historical sea surface temperature data sets, and biological observations from recent mass coral bleaching events (available in the literature and via Reefbase). The work will be conducted in four steps. First, building on previously published work by Dr. Simon Donner (Donner et al., 2005, 2007, 2009), we will develop and test an updated version of the NOAA Coral Reef Watch method for predicting the occurrence of mass coral bleaching to explicitly consider the historical climate that the reef has experienced. Second, we will downscale the coarse resolution projections from GFDL's state of the art global earth system model onto the reef scale using the temperature and chemistry data products developed by Coral Reef Watch. Third, we will use the global model results to project the frequency of mass coral bleaching events for coral reefs worldwide at moderate resolution under different scenarios of future greenhouse gas emissions. Finally, we will estimate the trajectory of coral cover around the world under the different future scenarios using observed rates of recovery from mass bleaching events and considering the potential effect of reduced coral calcification due to ocean acidification on recovery rates. The core research and development work will be conducted by a post-doctoral associate and graduate student under the direct supervision of Dr. John Dunne and Dr. Simon Donner, with assistance from Dr. Mark Eakin.

General Circulation Model Simulations of Martian Dust Storm Activity

R. John Wilson

FY 2010 Funding: $91,000

Abstract

The outstanding problem for simulating the present Mars climate is representing the spatial and temporal variability of aerosol and the feedbacks that connect dust raising and transport with the evolving atmospheric circulation. Interannual variability is dominated by episodic planet-encircling dust storms, which represent a spectacular radiative/dynamical feedback resulting from the mobilization and subsequent transport of dust. Another prominent aspect of the dust cycle is the emergence of large regional dust storm events that occur in the pre and post solstice periods of the northern hemisphere (NH) winter season. These events are initiated by midlatitude traveling waves in the NH that raise dust that is occasionally transported southward within low-lying channels into the southern (summer) hemisphere. These so-called flushing storms appear to be a relatively regular aspect of the dust cycle, although their impact varies from year to year. Local dust storm activity along the boundaries of the retreating CO2 polar caps is a basic feature of the dust cycle. To date, published efforts to simulate the main features of the dust cycle have been unsuccessful in yielding realistic interannual variability for major dust storms and have also failed to reproduce the more regular influence of flushing storms.

We propose to continue the development and utilization of a Mars General Circulation Model (MGCM) for gaining an improved understanding of the degree to which dynamical and radiative interactions between aerosols, the atmospheric circulation and the surface control the seasonal and interannual variability of the present climate. We will examine the contribution and response to dust raising by the various circulation elements such as the Hadley circulation, thermal tides, slope winds, transient waves and the CO2 condensation flow. We intend to identify and explore the sensitivities of the positive and negative feedback mechanisms within the climate system.

Our simulations now include the influence of a finite reservoir of mobile dust. By imposing an inverse relationship between the surface stress threshold for dust lifting and the depth of dust at the surface, we have introduced a potentially important negative feedback that enables the model climate system to organize the surface dust distribution in such a way as to support interannual variations in major dust storm events. Water ice clouds contribute to the atmospheric thermal balance and may play a notable role in structuring the polar vortex in which the traveling waves that initiate flushing storm events are embedded. Our goal is to carry out high resolution multi-annual simulations of Martian climate that yield regional and planet-

encircling dust storm with realistic spatial and temporal variability. It is anticipated that an improved understanding and parameterization of dust lifting and surface characterization will significantly aid the development of useful weather forecasting capability, which could assist mission planning and spacecraft operations. It is expected that the ability to represent the dust cycle in simulations of the current Mars climate will be an important step for evaluating the geologic history of dust deposits across the planet.

ARC MARS General Circulation Model

R. John Wilson

FY 2010 Funding: $90,371

Abstract

The proposed scientific research involves the ongoing development and maintenance of a state-of-the-art comprehensive global climate model of the Mars atmosphere.

NOAA/GFDL will provide continued development and maintenance of the Flexible Modeling System (FMS), including dynamical cores and infrastructure for running the code on a range of parallel computer architectures and managing I/O. John Wilson will coordinate this transfer of this code and provide the necessary support in its adaptation and use. He will play an important role in adapting current Mars physical parameterizations in the new model and will contribute to the design and evaluation of scientific studies based on the evolving climate model.

Towards GEOS- - A Non-hydrostatic Modeling Capability

S-J Lin and Max J. Suarez/ GFDL

FY 2010 Funding: $188,955

Abstract

We propose to implement and test a new cubed-sphere finite-volume, non-hydrostatic dynamical core developed at NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) for use in future GMAO atmospheric general circulation models. The core will be implemented under the MAPL software interface to the Earth System Modeling Framework (ESMF) used in GMAO systems. It will be tested at various resolutions in climate, numerical weather prediction (NWP), and data assimilation modes. We will evaluate the core's hydrostatic and non-

hydrostatic options at resolutions from 15 to 50 km, and will compare the resulting non-hydrostatic implementations at the two centers using resolutions as close to cloud-resolving as computing resources will allow (~5km).

For the GMAO, this proposal prepares the pathway to the next generation GEOS-6 system. For GFDL it will provide additional resources for a more thorough evaluation of the core and particularly of its performance at very high resolution in a numerical weather prediction (NWP) setting using the GMAO's atmospheric data assimilation system. The non-hydrostatic finite volume dynamical core is already undergoing advanced testing at GFDL and a hydrostatic version using the same code base is being tested at GMAO.

This collaboration between GMAO and GFDL will further the interests of both parties in the development of advanced climate and NWP models, and represents a key step in ensuring NASA's ability to continue to analyze and assimilate high-resolution satellite data using state-of-the-art models.

Effects of Global Change on Asian Pollution Outflow and Long-range Transport

Larry Horowitz

FY 2010 Funding: $27,744

Abstract

Asia will emerge over the next decades as the largest anthropogenic contributor to the global budgets of a number of environmentally and radiatively important trace gases. Long-range transport of pollution has implications for both global atmospheric chemistry and for regional environmental impacts on receptor continents. On the other hand, climate change can influence both transport of ozone (and its precursors) by affecting meteorology and ozone formation by affecting tropospheric chemistry. Understanding how changes in climate and in anthropogenic emissions of ozone precursors affect the meteorological and chemical processes associated with the Asian continental outflow as well as the long-range transport of this outflow is crucial for future projections of Asian influence on global tropospheric chemistry, oxidation capacity, hemispheric transport of pollution and U.S. surface air quality, and for informing international environmental policies.

We propose a 4-year project to examine the effects on Asian pollution outflow and long-range transport from IPCC A1B 2000-2050 global changes in climate and anthropogenic

emissions of ozone precursors by using the Global Modeling Initiative (GMI) chemistry transport model (CTM) driven by meteorological fields from the NOAA GFDL's new atmospheric general circulation model (AM3). The effects from climate change and from changes in anthropogenic emission for ozone precursors will be studied separately and then together through an ensemble of sensitivity simulations.

Our research objectives are:

To improve our understanding of uncertainties in model predictions due to the use of different input meteorological fields by incorporating output from the GFDL AM3 model into the GMI modeling framework;

To assess the AM3 meteorological fields through intercomparison with those from other major global climate models or data assimilation systems;

To synergistically improve and develop the representation of precipitation scavenging in AM3 and GMI using constraints from radionuclide tracers.

(2) To understand and quantify the effects of global change on transport pathways and chemical outflow for Asian pollution to the western Pacific, low latitude easterly outflow to the Middle East and to the UT/LS via vertical transport over the Tibetan Plateau;

(3) To assess and quantify the effects of changes in climate and anthropogenic emissions on the source-receptor relationships for ozone pollution.

This project will make available to GMI science team members a new set of meteorological fields for sensitivity studies and provide important insights into the strength and weakness of the AM3 meteorology. Meteorological fields representative of 2050 (A1B scenario) simulated with AM3 may also be used by GMI science team members to study the sensitivities of atmospheric composition to climate change. Our work will result in an improved and more self-consistent representation in large-scale models of precipitation scavenging of soluble gases and aerosols important for tropospheric chemistry, directly answering a recent call made by GMI to the scientific community. This project will allow us to contribute GMI/AM3 modeling results to the HTAP and AC&C activities for model intercomparison in the context of the impact of global change on intercontinental transport of pollution.

This proposal specifically answers this solicitation that seeks "investigations that contribute to a synergistic interaction between GMI and general circulation models (GCMs)" and "fully coupled chemistry climate models (CCMs)". Our proposed research directly address NASA's science questions "How does the Earth system respond to natural and human-induced changes?" and "How will the Earth System change in the future?" and meets NASA's research objective to “understand and improve predictive capability for changes in the ozone layer, climate forcing, and air quality associated with changes in atmospheric composition”.